The Labadie, Jones and Cockburn Banks *Nephrops* Grounds (FU2021) 2017 UWTV Survey Report and catch options for 2018.

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Abstract

This report provides the main results of the 2017 underwater television survey on the 'Labadie, Jones and Cockburn Banks' ICES assessment area; Functional Unit 20-21. This was the fourth survey to achieve full coverage of the full area. The 2017 survey was multi-disciplinary in nature collecting UWTV, CTD and other ecosystem data. A total of 86 UWTV stations were completed at 6 nmi intervals over a randomised isometric grid design. The mean burrow density was 0.44 burrows/m^2 compared with 0.18 burrows/m^2 in 2016. The 2017 geostatistical abundance estimate was 4.4±0.01 billion a 236% increase on the abundance for 2016 with a CV of 4% which is well below the upper limit of 20% recommended by SGNEPS 2012. Highest densities were generally observed throughout the ground, and there were also high densities observed close to boundaries. Using the 2017 abundance estimate and updated stock data implies catch of 8,673 tonnes and landings of 6,553 tonnes in 2018 when MSY approach is applied (assuming that discard rates and fishery selection patterns do not change from the average of 2014–2016). One species of sea-pen were recorded as present at the stations surveyed *Virgilaria mirabilis.* Trawl marks were observed at 32% of the stations surveyed.

Key words: *Nephrops norvegicus,* Celtic Sea, stock assessment, geostatistics, underwater television (UWTV), CTD, benthos.

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Introduction

The prawn (*Nephrops norvegicus*) are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas were the sediment is suitable for them to construct their burrows. The *Nephrops* fishery in ICES sub-area 7 is extremely valuable with landings in 2016 worth around €107 million at first sale. The Celtic Sea area (Functional Units 19-22 see Figure 1) supports a large multi-national targeted *Nephrops* fishery mainly using otter trawls and yielding landings in the region of ~5,000 t annually over the last decade (ICES, 2017). The 2016 reported landings from this FU20-21, ~2,400 t were estimated to be worth in the region of €13.6 m at first sale. This ground has become increasingly important to the Irish demersal fleet which now account for over 70% of the FU20-21 *Nephrops* landings (ICES, 2017). Good scientific information on stock status and exploitation rates are required to inform sustainable management of this resource.

Nephrops spend a great deal of time in their burrows and their emergence behaviour is influenced by several factors: time of day, time of year, light intensity, tidal strength, etc. Underwater television surveys and assessment methodologies have been developed to provide a fishery independent estimate of stock size, exploitation status and catch advice (ICES, 2009a & 2012a). This is the fifth UWTV survey in the Celtic Sea FU20-21 grounds carried out by the Marine Institute, Ireland.

The survey was multi-disciplinary in nature and also covered TV stations in FU19 the results of which are presented elsewhere (Doyle et. al., 2017). The 2017 specific objectives are listed below:

1. To complete ~86 UWTV stations with 6.0 nautical mile (Nmi) spacing stations on the Labadie, Jones and Cockburn *Nephrops* ground (FU2021).
2. To obtain 2017 quality assured estimates of *Nephrops* burrow distribution and abundance. These will be compared with those collected previously.
3. To collect ancillary information from the UWTV footage collected at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the sea bed.
4. To collect oceanographic data using a sledge mounted CTD.

This report details: the survey design, the final UWTV results of the 2017 survey and also documents other data collected during the survey. Operational survey details are available in form of a survey narrative from the scientist in charge (JD). The 2017 abundance are used to generate catch options for 2018 in line with the recommendations and procedures outlined in the stock annex for FU20-21 (ICES, 2017).

Material and methods

The knowledge about the distribution of suitable *Nephrops* habitat in this area has been developing. Information so far suggests that *Nephrops* are found in complex channels, which are probably the remnants of fluvial channels related to the deglaciation of the Irish ice sheet at the end of the last ice age. The ground area was revised by WKCELT (ICES, 2014) to include both French and Irish integrated logbook VMS data(Gerritsen & Lordan, 2011) and is now calculated at 10 014 km² and this value is used for the survey. The 2017 randomised isometric grid which resulted in 86 planned stations was generated using the "spsampl" function in the "sp" package (Pebesma & Bivand, 2005) in "r" (R Core Team, 2017). Stations depths varied from 84 m to 133 m and the completed stations ranged from 55 to 135 nautical miles (nmi) offshore (Figure 2). The 2017 survey took place on the RV. Celtic Voyager: from the 3rd to 13th July.

The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and employed on other UWTV surveys in Irish waters. These protocols can be summarised as follows: At each station the UWTV sledge was deployed. Once stable on the seabed a 10 minute tow was recorded onto DVD. Time referenced video footage was collected from a video camera with field of view or 'FOV' of 75 cm. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 2 seconds. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b). The USBL navigational data was used to calculate distance over ground or 'DOG' for 99 % of stations.

In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and reference footage from this area, prior to recounting at sea (ICES, 2009b). All recounts were conducted by two trained "burrow identifying" scientists independent of each other on board the research vessel during the survey. During this review process the visibility, ground type and speed of the sledge during one-minute intervals were subjectively classified using a classification key. In addition the numbers of *Nephrops* burrows complexes (multiple burrows in close proximity which appear to be part of a single complex which are only counted once), *Nephrops* activity in and out of burrows were counted by each scientist for each one-minute interval was recorded. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009b).

Notes were also recorded each minute on the occurrence of trawl marks, fish species and other species. Abundance categories of sea-pen species were also recorded due to OSPAR Special Request (ICES 2011) using the scale provided in Table 1. Finally, if there was any time during the one-minute where counting was not possible, due to sediment clouds or other reasons, this was also estimated so that the time window could be removed from the distance over ground calculations. The "r" quality control tool allowed for individual station data to be analysed in terms of data quality for navigation, overall tow factors such as speed and visual clarity and consistency in counts (Figure 3).

In 2017 the survey count data was screened to check for any unusual discrepancies using Lin's Concordance Correlation Coefficient (CCC) with a threshold of 0.5. Lin's CCC (Lin, 1989) measures the ability of counters to exactly reproduce each other's counts on a scale of 1 to –1 where 1 is perfect concordance (i.e. a pairwise plot will have all points lying along the 1:1 line. A value of –1 would be generated by all points lying on the –1:1 line and a value of 0 indicates no correspondence at all. This analysis resulted in 32 stations that required a third counter approximately 40% of total TV stations. For those stations that did not pass the threshold it was deemed appropriate to inspect the CCC plots and then to use the 3 counters in the final counts. Lin's CCC quality control plots of count data for stations 120 to 122 are shown in Figure 4. Consistency and bias between individual counters was examined using Figure 5. There is moderate variability between counters but no obvious bias or excessive deviations. The moderate variability between counters is because burrow counting in this area is particularly difficult (see discussion).

Mean density was calculated by dividing the total number of burrow systems by the survey area observed. The USBL data were used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated at 75cm assuming that the sledge was flat on the seabed (i.e. no sinking). This field of view was confirmed during the 2017 survey using lasers. Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud (the impact of this is a minor under estimate of densities at stations where this occurred).

At each station CTD data was logged using a sled mounted and calibrated Seabird SBE 37. The sensor takes readings every 5 seconds and will be processed at a later stage.

The approach to work up the abundance estimates each year has been documented in previous survey reports. Since 2015 the geostatistical analysis was carried out using RGeostats package (Renard D., *et al*, 2015) and is available as an R markdown document. The same steps were carried out as in previous years; construction of experimental variogram, a model variogram $\gamma(h)$, was produced with exponential model, create kriged grid file using all data points as neighbours, same boundary used to estimate the domain area, mean density, total burrow abundance and then calculate survey precision.

Results

All 86 stations were completed successfully on the FU20-21 *Nephrops* grounds (Figure 2). Figure 6 shows bubble plots of the variability between minutes and operators. These show that the burrow estimates are fairly consistent between minutes and counters. The variability is slightly higher between minutes then between counters.

The adjusted burrow densities in 2013 to 2017 are shown in Figure 7 as a combined violin and box plot. These show that density has increased significantly in 2017 with high densities (>0.7/m^2) observed and the majority of densities in the moderate range (0.7-0.3/m^2). The 2017 mean adjusted[1] density of 0.44 burrows/m^2 is the highest in the time series to date and was 236% higher than 2016 estimate of 0.18 burrows/m^2. There were 3 observations of adjusted burrow density >1.0 burrows/m^2.

Combined bubble and contour plot of the krigged density from 2013 to 2017 are presented in Figure 8. Highest densities were towards the centre of the ground in years 2013-2014 and 2015 - 2016 shows high densities in the northern and southwestern area. In 2017 high densities were generally observed throughout the ground but the highest were to the northwest. There were also high densities observed close to boundaries in several areas.

[1] Note the “adjusted” density estimates in this report are adjusted by dividing by 1.3 (Table 2) to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

The summary empirical and geo-statistical results are given in Table 2. There were some stations were carried out in 2006 and in 2012 these should be viewed as exploratory surveys and have not been used to extrapolate total abundance. The 2013 survey had partial coverage of the area (<60%) scaling the mean density to the total area (10,014 km^2) resulted in an abundance estimate of 1.6±0.3 billion. The 2017 geo-statistical abundance estimate is 4.4±0.01 billion which is 236% higher than in 2016 (Figure 9). The geo-statistical CVs were in the order of 3 to 5 %. These are well below the upper limit recommended of <20% (ICES, 2012).

The UWTV abundance data together with data from the fishery; landings, discards and removals in number are used to calculate the harvest rate calculated as (dead removals/TV abundance) in 2016 of 4.7%. The mean weight in the landings and the discards and the proportions of removal retained are also shown (Table 3). The mean weights are variable between 2012 - 2016 but are based on the only available sampling data (ICES, 2017). The basis to the catch options is given in Table 4. The catch options and the associated harvest rates and catch are presented in Table 5. Fishing at F_{msy} of 6.0 % in 2018 would result in total catches of 8,673 t which implies landings of 6,553 t (Table 5).

Sea-pen distribution across the *Nephrops* grounds is mapped in Figure 10. All sea-pens were identified from the video footage as *Virgularia mirabilis*. Trawl marks were noted at 32% of the stations surveyed.

Discussion

The 2017 survey achieved full coverage of the stock area for the fourth time. The density estimates in 2013 - 2016 are relatively similar and would be considered low (mainly ~0.2m^2). In 2017 there was a large increase in the densities across the whole ground. A large increase in density was also observed in FU22 (O'Brien, et al., 2017). It is likely that the recruitment to *Nephrops* populations in the Celtic Sea are linked through oceanographic process (O'Sullivan et. al, 2015). It may well be that favourable oceanographic conditions have resulted in the observed density increases in both area.

Nephrops fisheries in this area are covered under the landings obligation since 2016. Discard rates in weight for this FU have been around 25% in recent years which is above the Landing Obligation *de minimus* of 7%. Because harvest rates are calculated on the basis of numbers and 25% of the *Nephrops* in this area are assumed to have survived discarding up to now this presents a problem in calculating catch options for 2018. Two scenarios are presented in Table 5. The first assumes that all catches will be landed in 2018 so the discards that would have survived will be landed. This is unlikely in practice. The second scenario assumes that discarding continues are the average rate estimated between 2014 and 2016. The difference in advised landings or catches between the two scenarios is relatively small ~11%.

The introduction of the landings obligation to *Nephrops* fisheries since 2016 should result in changes in selectivity. This is not taken into account in any of the catch advice because it is not possible to predict exactly what might happen. The main message is that any improvements in selectivity in the fishery and reductions in discards will result in increased mean weight in the catches. This will in turn reduce overall mortality on the stocks and allow for catch increases in the future.

An important objective of this UWTV survey is to collect various ancillary information. The occurrence of trawl marks on the footage is notable for two reasons. Firstly, it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult. Secondly, only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops* (ICES 2008). The CTD data collected during UWTV surveys will over time prove to be a data asset in monitoring changes to the environment on *Nephrops* grounds.

Acknowledgments

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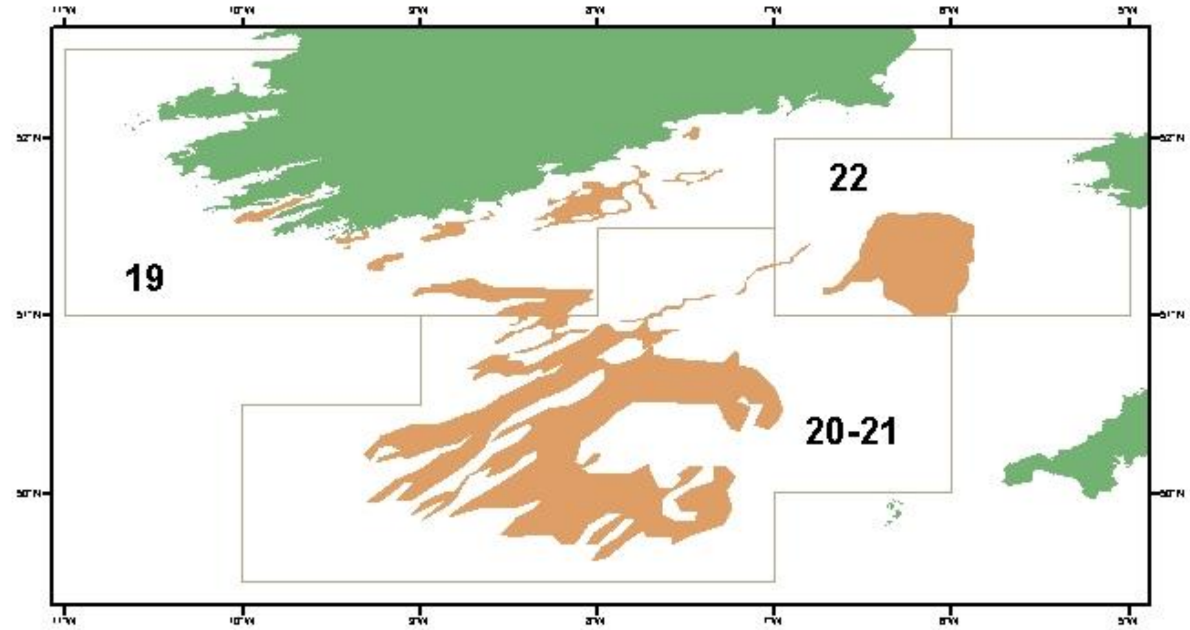

Figure 1:FU2021 grounds: *Nephrops* Functional Units (FUs) and *Nephrops* area polygons in the greater Celtic Sea.

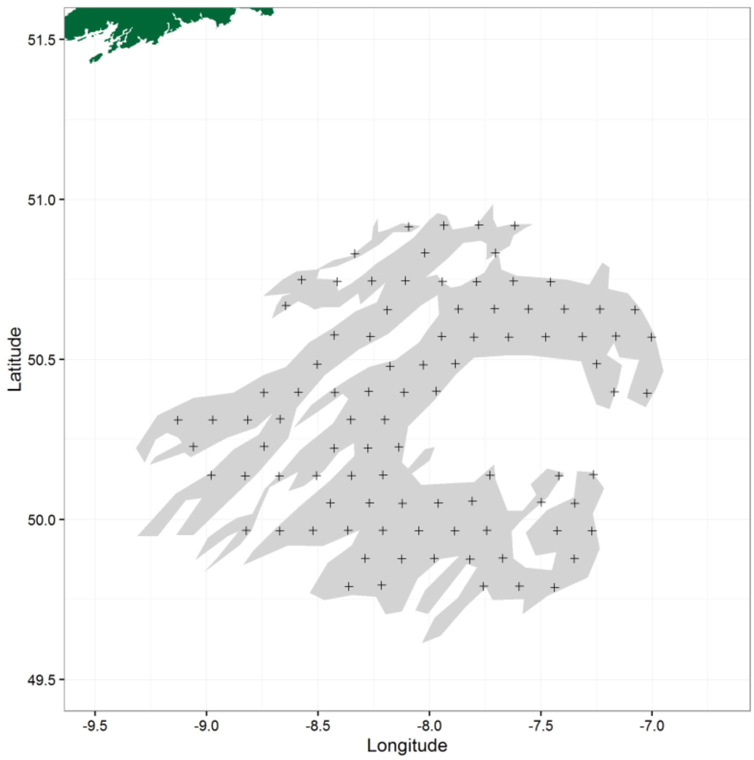

Figure 2: FU2021 grounds: TV stations completed on the 2017 survey.

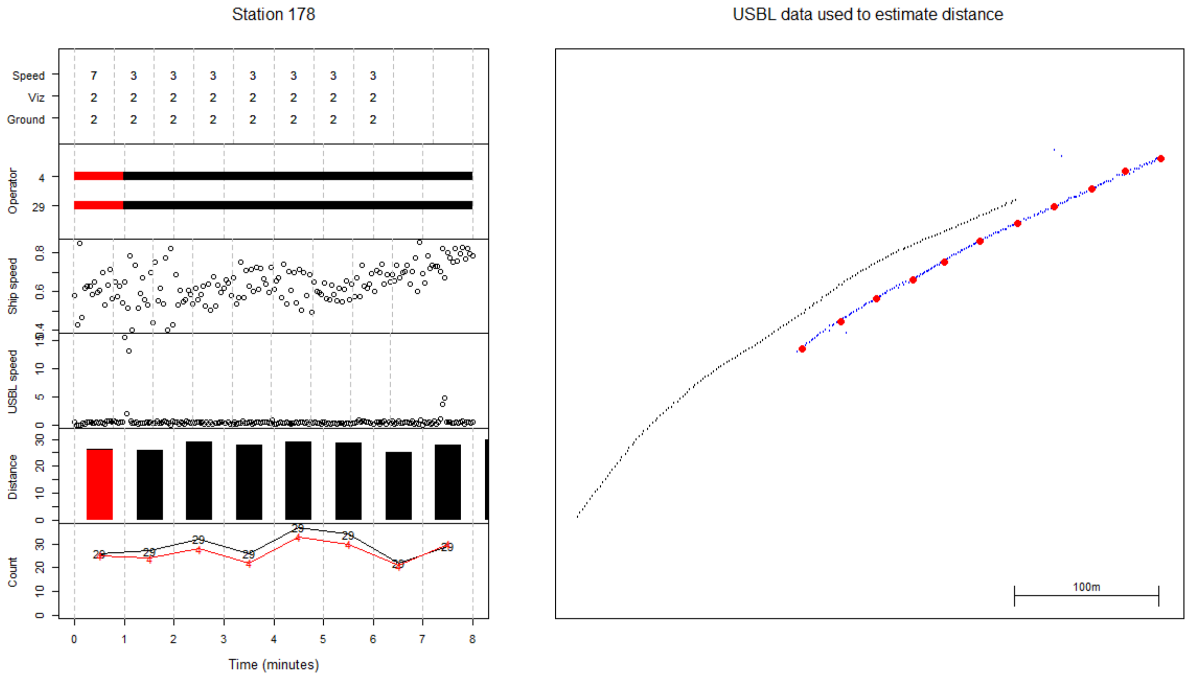

Figure 3: FU2021 grounds: r - tool quality control plot for station 178 of the 2017 survey.

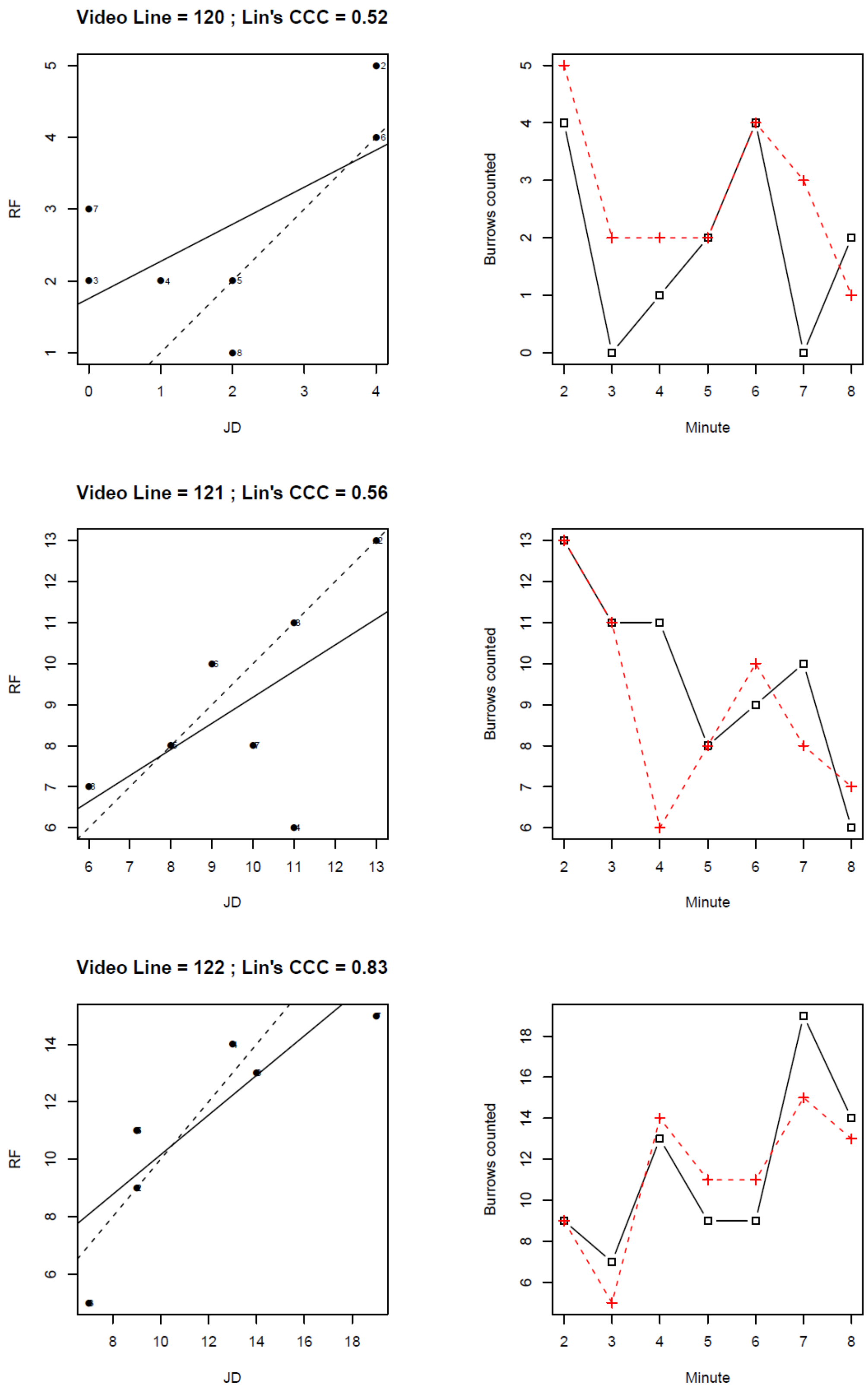

Figure 4: FU2021 grounds: Lin's CCC quality control plot of count data for stations 120-122 from the 2017 survey.

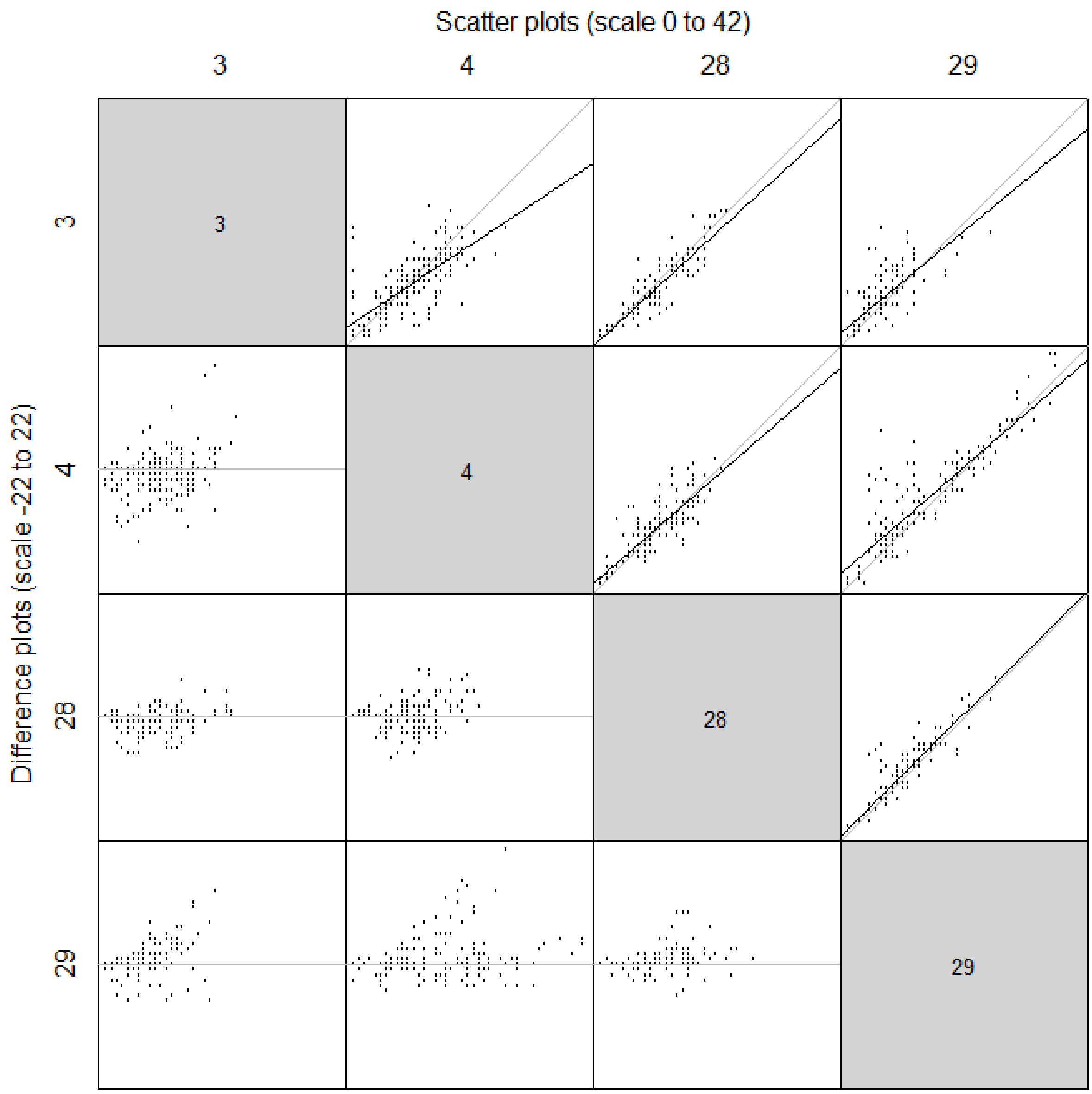

Figure 5: FU2021 grounds: Scatter plot analysis of counter correlations for the 2017 survey.

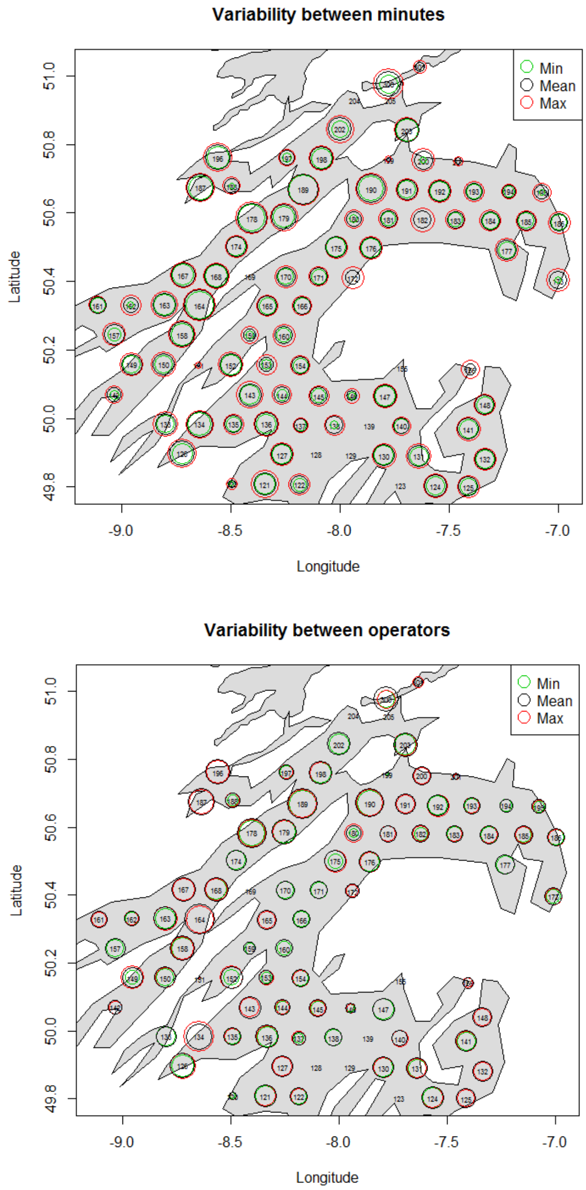

Figure 6: FU2021 grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2017.

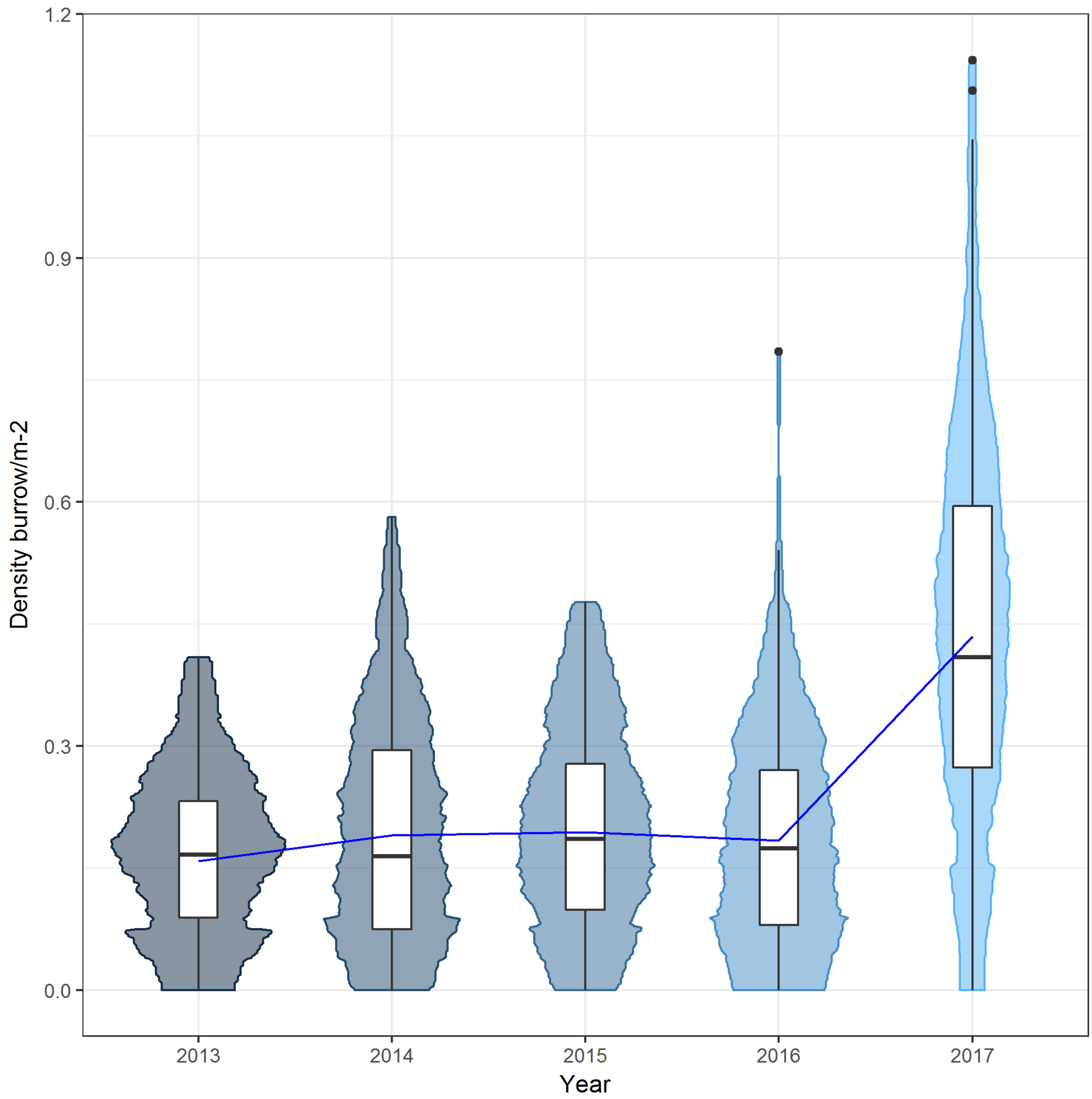

Figure 7 : FU2021 grounds: Violin and box plot a of adjusted burrow density distributions by year from 2013-2017. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

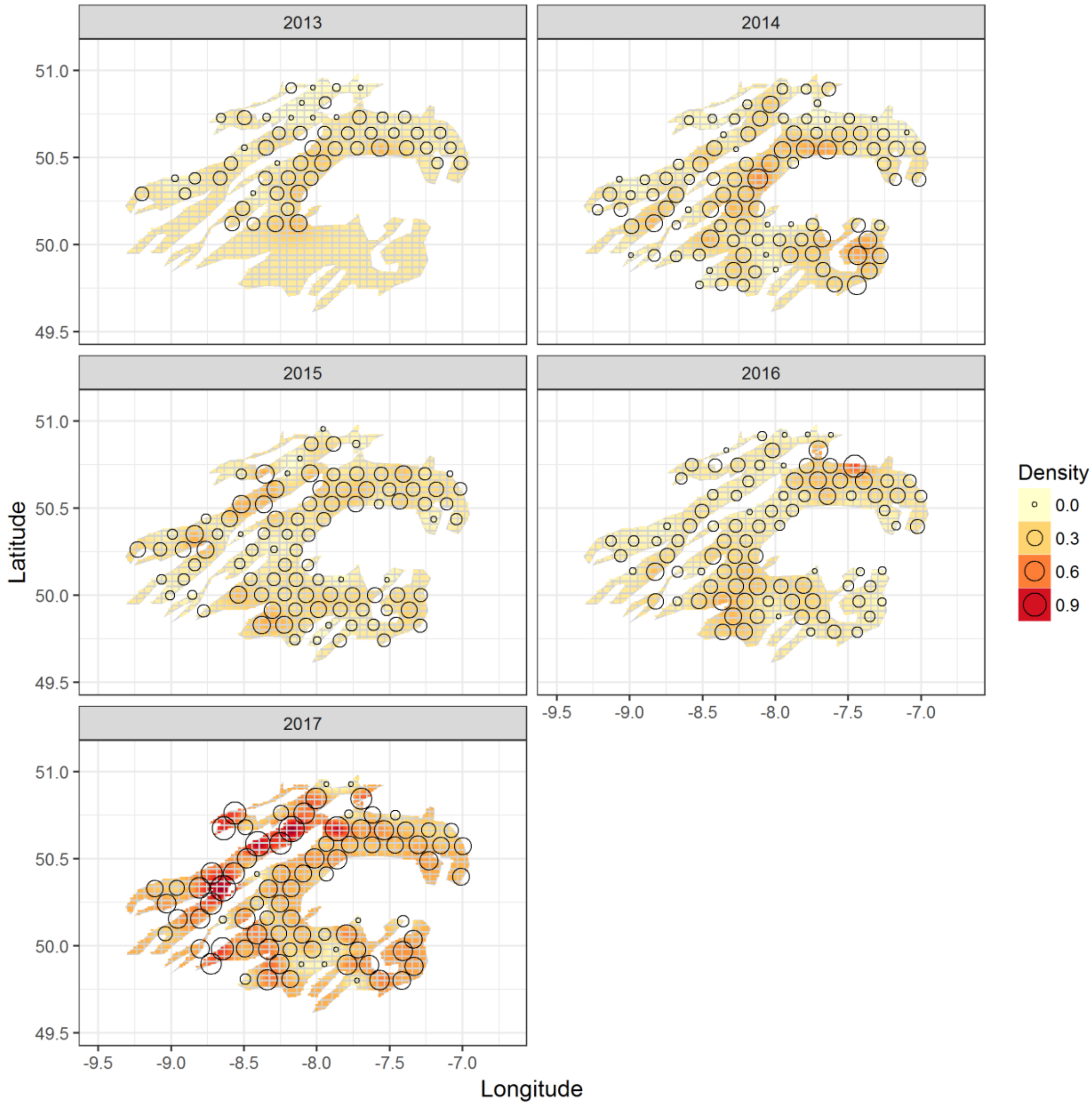

Figure 8: FU2021 grounds: Contour plots of the krigged density estimates by year from 2013 (top left) - 2017 (bottom left).

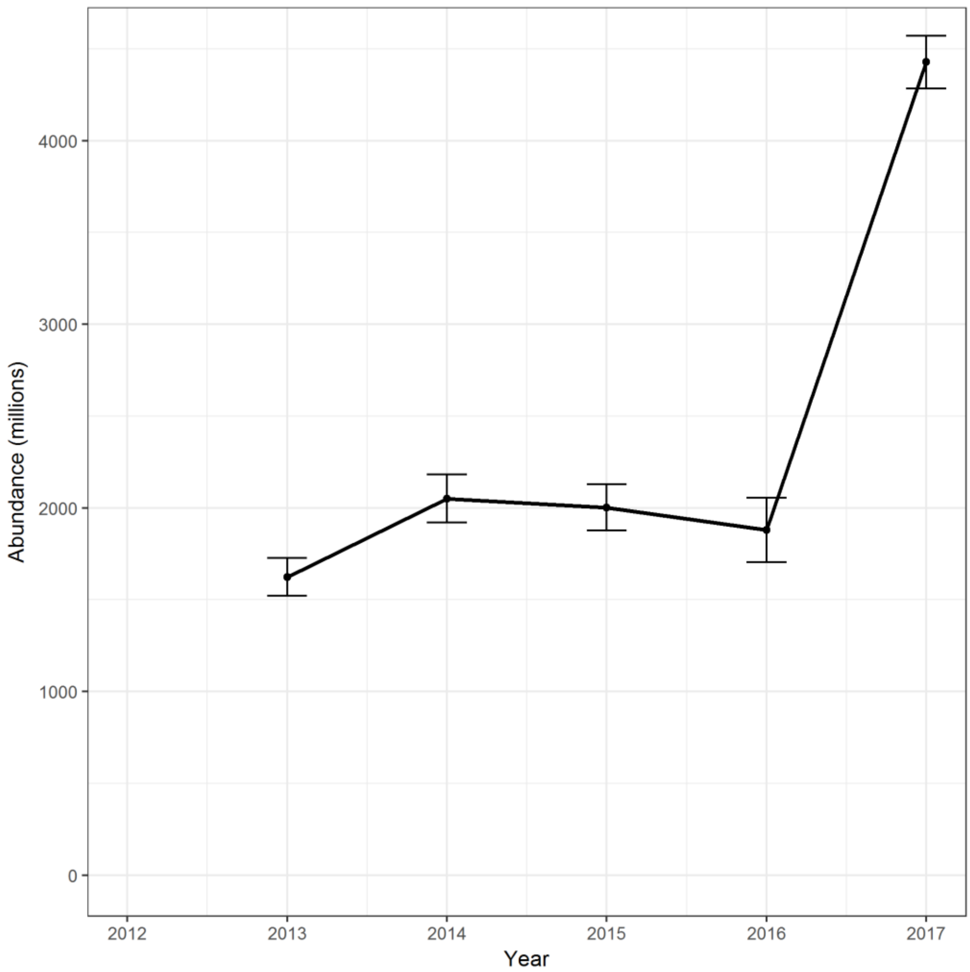

Figure 9: FU2021 grounds: Time series of raised abundance estimates (in millions of burrows) for FU2021. The error bars indicate the 95% confidence intervals.

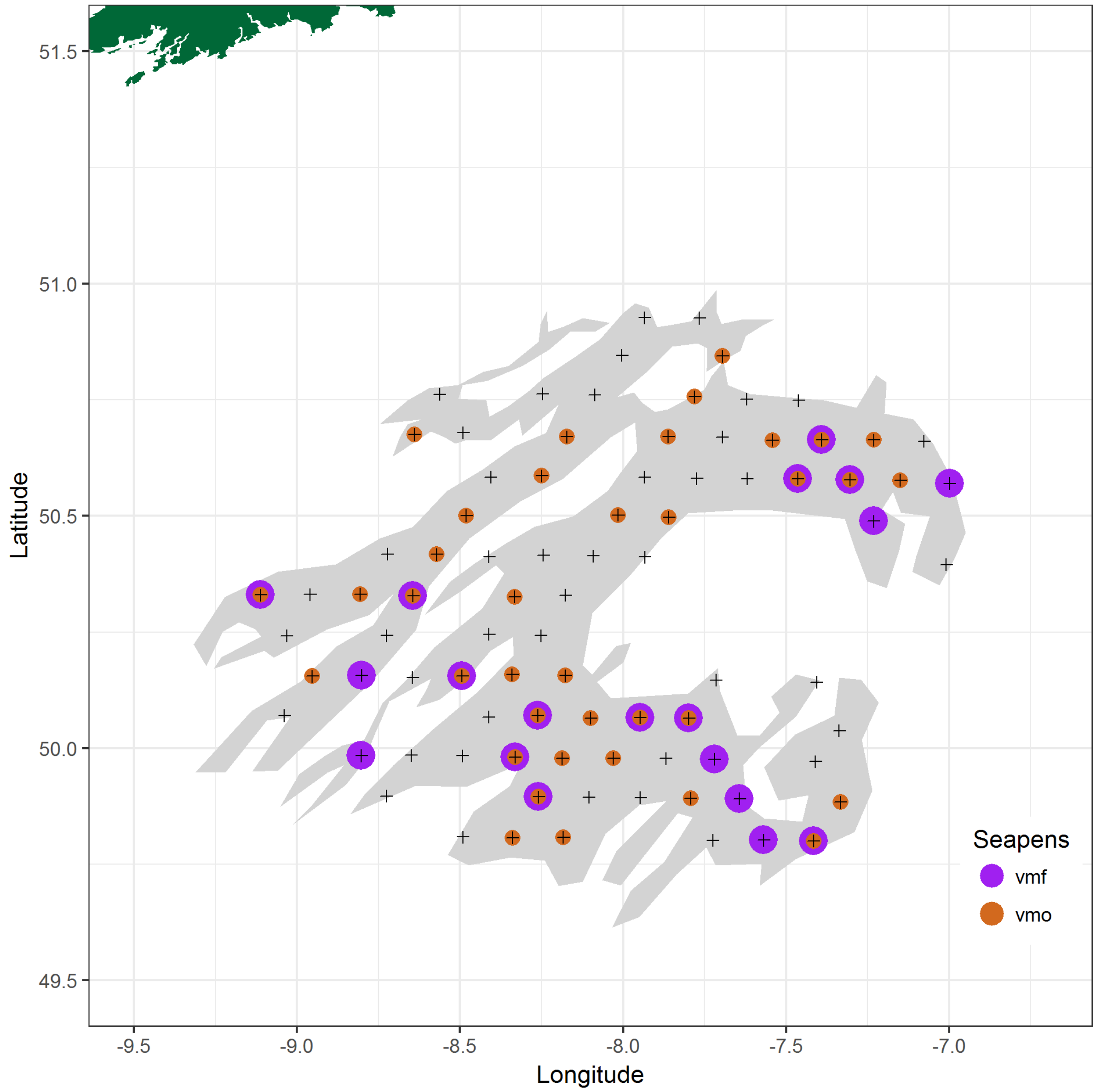

Figure 10: FU2021 grounds: 2017 stations where *Virgularia mirabilis* (VM) were identified and classified according to abundance key - occasional (o), frequent f), common (c).
(+) denotes TV stations with no sea-pen observations.

Table 1: Key for classification of sea-pen abundance as used on Irish UWTV surveys.

	Number/Min
Common	20-200
Frequent	2-19
Ocasional	<2

Species

Virgularia mirabilis
Pennatula phosphorea
Funiculina quadrangularis

Sea Pens								
V. mirabilis			*P. phosphorea*			*F. quadrangularis*		
C	F	O	C	F	O	C	F	O

Table 2: Summary of UWTV results; number of stations, mean density observed, standard deviation, absolute abundance estimates with 95% confidence intervals, estimated area of the stock and coefficient of variation on the abundance.

Year	Number of stations	Mean Density adjusted (burrow /m²)	Standard Deviation	Absolute abundance estimate (million burrows)	95% CI on Abundance	Domain area	CVs
2006	9	0.44	0.31	nr			
2012	54	0.57	0.25	nr			
2013	55	0.16	0.11	942	60	5701	3%
2013*				1624	103	9835	
2014	98	0.19	0.14	2051	131	9835	3%
2015	96	0.20	0.02	2003	125	9835	3%
2016	93	0.18	0.02	1879	175	9835	5%
2017	86	0.44	0.08	4428	145	9835	4%

* the 2013 survey achieved partial coverage ~60% of the total area. The abundance has been scaled up to the entire area since densities in the unsurveyed part of the ground were not significantly different in 2014.
nr= no reliable abundance estimate could be calculated because survey coverage was partial.

Table 3: Inputs to short-term catch option table.

Year	Landings in number	Total discards in number	Removals in number	UWTV abundance estimates	95% Conf. intervals	Harvest rate	Mean weight in landings	Mean weight in discards	Discard rate	Dead discard rate
	millions	millions	millions	millions	millions	%	grammes	grammes	%	%
2012	38.2	36.1	65.3				31.1	15.0	49%	41%
2013	34.8	19.2	49.2	1624	103	3.0%	39.9	17.0	36%	29%
2014	50.6	55.5	92.2	2051	131	4.5%	36.3	15.0	52%	45%
2015	59.4	28.1	80.5	2003	125	4.0%	35.7	15.7	32%	26%
2016	60.2	37.5	88.3	1879	175	4.7%	40.7	21.4	38%	32%
2017				4428	145					

Table 4: The basis for the catch options for 2017.

Variable	Value	Source	Notes
Stock abundance	4428	ICES (2017)	UWTV survey 2017
Mean weight in landings	37.6 g	ICES (2017)	Average 2014–2016
Mean weight in discards	17.4 g	ICES (2017)	Average 2014–2016
Discard rate	41.0%	ICES (2017)	Average 2014–2016 (by number). Calculated as discards divided by landings + discards.
Discard survival rate	25%	ICES (2017)	Only applies in scenarios where discarding is allowed.
Dead discard rate	34.4%	ICES (2017)	Average 2014–2016 (by number). Calculated as dead discards divided by dead removals (landings + dead discards). Only applies in scenarios where discarding is allowed.

Table 5: Short-term management option table giving catch options for 2018 using the 2017 UWTV survey estimate.

a) Catch options for 2018 assuming zero discards.

Basis	Total catch	Wanted catch*	Unwanted catch*	Harvest rate**
ICES advice basis				
MSY approach; F_{MSY}	7789	5894	1895	6.0%
Other options				
$F_{current}$ (2014–2016)	5712	4322	1390	4.4%

* "Wanted" and "unwanted" catch are used to describe *Nephrops* that would be landed and discarded in the absence of the EU landing obligation, based on the average estimated discard rates for 2014–2016.
** Calculated for dead removals and applied to total catch.

b) Catch options for 2018 assuming discarding to continue at recent average**.**

Basis	Total catch	Dead removals	Landings	Dead discards	Surviving discards	Harvest rate*
	L+DD+SD	L+DD	L	DD	SD	for L+DD
ICES advice basis						
MSY approach; F_{MSY}	8673	8143	6553	1590	530	6.0%
Other options						
$F_{current}$ (2014–2016)	6361	5972	4806	1167	389	4.4%

* Calculated for dead removals and applied to total catch.